J E M T
Journal of Earth and Marine Technology
homepage URL: ejurnal.itats.ac.id/jemt

Productivity Analysis of Digging, Loading, and Hauling Equipment in Overburden Removal Activities at PT. Anugrah Borneo Sinergy in Keramat Mina field, South Kalimantan, Indonesia

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Article info
Received:
Aug 10, 2024
Revised:
Dec 10, 2024
Accepted:
Dec 23, 2024
Published:
Dec 31, 2024

Keywords:
Cycle time, work efficiency, match factor, productivity

Abstract

This study evaluates the productivity of loading and hauling equipment at Anugrah Borneo Sinergy Ltd., explicitly focusing on compatibility between these units and identifying obstacles in overburdening material transfer activities. Employing a direct observation method at pit 1 in Keramat Mina Village, this research spanned a day shift from August 20 to September 20, 2022. Productivity measurements were taken for the Sany SY 365 H Excavator and the Hino 500 FM 260 JD Dump Truck, alongside employee interviews for supplementary data. Results indicate that the excavator's productivity varied daily, averaging 136.07 Bcm/hour, while the dump truck averaged 56.19 Bcm/hour over the same period, both below the target of 170 Bcm/hour. Initial compatibility assessment yielded a match factor of 0.83, which improved to 1.18 after optimizing cycle times. Simulating the compatibility with an additional hauler resulted in a perfect match factor of 1. Key obstacles included extended waiting and haul times, inefficiency, and an imbalance in the number of loaders versus haulers. Recommendations to enhance productivity involve optimizing loading efficiency and reducing haul, return and wait times. Post-optimization, productivity improved significantly, reaching 163.28 Bcm/hour for loaders and 88.29 Bcm/hour for haulers, thus meeting production goals. Adding another hauling unit could sustain these improvements by achieving optimal equipment compatibility.

1. Introduction

The productivity of mining operations, particularly in overburden removal, is crucial for the economic and environmental sustainability of the mining industry. This importance is underscored by the escalating demand for coal, driven by its critical role in energy production and economic growth, particularly in regions like Indonesia. However, achieving optimal productivity is challenging due to the complex nature of mining operations and the efficiency of the equipment used. Specifically, operations at PT. Anugrah Borneo Sinergy is falling short of its production target of 170 Bcm/hour, highlighting the need for a detailed productivity analysis and optimization.

Research and practice have demonstrated that various strategies and equipment can improve productivity outcomes, for example, at PT. Artamulia Tata Pratama, implementing the queuing method and optimizing the match factor for the number of dump trucks significantly enhanced productivity, illustrating the importance of strategic equipment management [15]. Similarly, PT Pertama Mina Sutra Perkasa focused on reducing obstacle time, a crucial step for meeting productivity targets by improving the efficiency of loading and hauling equipment [16].

Several factors influence the productivity of digging, loading, and hauling equipment, including adequate working time, tool efficiency, and the number of tools used. Enhancing the work efficiency of these tools at PT. Batu Anugrah Mineral Resources led to a notable increase in production capacity, aligning closer to the 170 Bcm/hour target [14]. Additionally, factors such as circulation time, bucket capacity, fill factor, and material expansion factor play significant roles in determining equipment productivity [17]. External conditions like weather and road quality also considerably impact equipment performance and production outcomes [17].

To further improve productivity, mining operations can adopt various strategies. Reducing avoidable barrier times and increasing adequate working time are essential. For instance, PT. Batu Anugrah Mineral Resources and PT Pertama Mina Sutra Perkasa achieved better results by optimizing tool distribution and enhancing work efficiency [14], [17]. Moreover, ensuring proper maintenance and operation of equipment, along with strategic planning and scheduling, are vital for enhancing productivity in overburden removal activities.

This study seeks to address these challenges by analyzing mining equipment's technical specifications and operational efficiencies. By employing a comprehensive approach that considers equipment capabilities, operational constraints, and field conditions, this research aims to develop a more robust productivity model in overburden removal at PT. Anugrah Borneo Sinergy. Such an approach is increasingly crucial as the demand for coal and the pressure to extract it efficiently and sustainably continue to rise, a theme underexplored in existing literature despite its critical importance to Indonesia's economic and environmental future.

2. Methodology

Research Design This study employed a quantitative research design to evaluate loading and hauling equipment productivity at PT. Anugrah Borneo Sinergy. The primary objective was to identify operational inefficiencies and optimize equipment use to meet the target production of 170 Bcm/hour. The research spanned one month, from August 20 to September 20, 2022, incorporating both direct observations and empirical data collection (Figure 1), following methodologies similar to those described by Peurifoy [8] for assessing construction equipment performance.

Data Collection Data were collected through two primary methods:

1. Direct Observation: Researchers conducted onsite observations at pit 1 of PT. Anugrah Borneo Sinergy, recording operational processes in real-time. This included the monitoring of equipment cycle times, operational delays, and the effectiveness of equipment interactions, a method validated by Fanani et al. [5] in their studies on equipment performance.
2. Structured Interviews: Interviews were conducted with site operators and management staff to gain insights into operational challenges and current practices' effectiveness, as Indonesianto [6] recommended for capturing qualitative insights from operational staff.

Equipment Monitored The specific equipment monitored included:

- Sany SY 365 H Excavator
- Hino 500 FM 260 JD Dump Truck The performance metrics assessed were similar to those described in the studies by Hadi et al. [3], including cycle times, loading capacities, and operational downtimes.

Data Analysis Data analysis involved the following steps:

1. Cycle Time Analysis: Using the recorded data, the cycle times for each piece of equipment were analyzed to assess efficiency and identify bottlenecks in the material handling process, an approach supported by methodologies detailed in [10].
2. Productivity Calculation: Productivity was calculated by measuring the volume of overburden moved per hour against the operational time recorded, aligning with techniques outlined by Mustofa et al. [7].
3. Match Factor Optimization: The match factor between the excavators and dump trucks was calculated to determine the efficiency of their interaction, following the principles discussed by Gusman et al. [15] for optimizing equipment deployment.

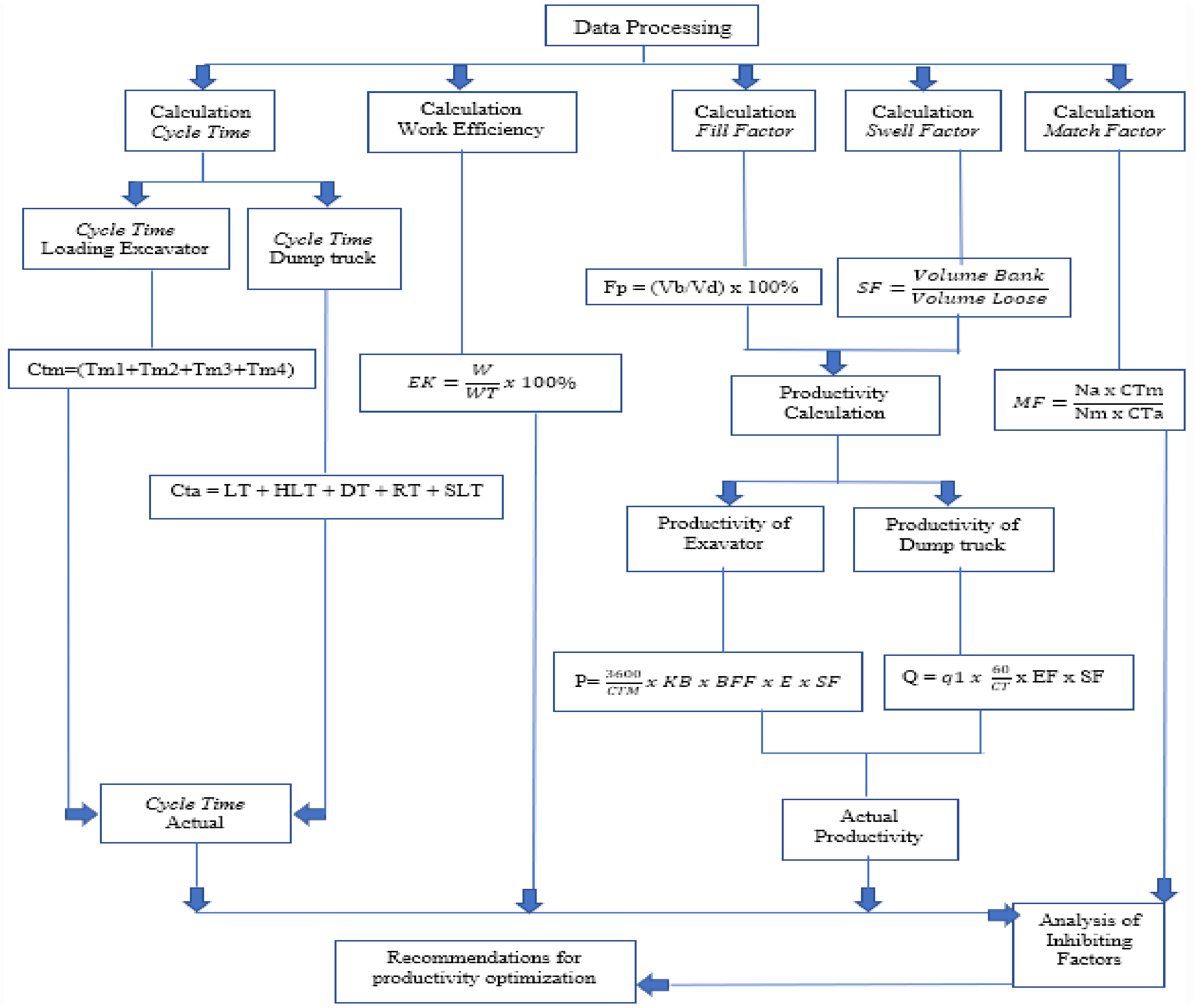


Figure 1. Data processing flowchart

3. Results

Mechanical equipment used at the research site

Table 1 provides an overview of the mechanical equipment employed in the productivity analysis at PT. Anugrah Borneo Sinergy. The table categorizes the equipment into two main types: loading excavators and transport equipment. The loading excavator category includes a single Sany SY 365 H unit, which boasts a bucket capacity of 1.6 BCM (Bank Cubic Meters), designed for heavy-duty mining operations. In the transport equipment category, there are two units of the Hino 500 FM 260 JD, each with a capacity ranging from 8 to 10 BCM. This capacity range indicates the variability in load size that these trucks can handle, making them versatile for various mining tasks. The data summarized in this table is critical for understanding the scale of operations and the potential volume of material that can be moved during the mining process at the site.

Table 1. Number and type of mechanical equipment

Type	Unit Type	Number of Units	Capacity (BCM)
Loading Excavator	Sany SY 365 H	1	1,6
Transport Equipment	Hino 500 FM 260 JD	2	8 - 10

Table 2. Cycle Time Excavator

Cycle Time Excavator				
Day	Digging time (s)	Swing time full (s)	Dump (s)	Swing time empty (s)
20.08.2022	7,51	7,01	2,51	6,53
21.08.2022	7,52	5,87	2,51	5,55
22.08.2022	6,52	5,54	2,49	6,16
23.08.2022	6,57	8,29	2,42	7,52
24.08.2022	6,01	6,93	2,46	6,31
25.08.2022	11,41	5,92	2,43	5,97
26.08.2022	8,53	7,98	2,48	6,57

Cycle time excavator

Cycle time is the total duration required by mechanical equipment, explicitly digging and loading machinery, to complete an entire cycle of production activities. This period begins with the commencement of the operation and concludes when the equipment is ready to initiate the next cycle. The importance of optimizing cycle time lies in its direct impact on the productivity and efficiency of mining operations, as shorter cycle times can lead to higher output rates [4].

In an assessment conducted at the research site, cycle times for the SANY SY 365 H excavator were meticulously recorded to evaluate operational efficiency over several days. The observations commenced on August 20, 2022, when the cycle time was documented at 23.56 seconds. Over the next few days, a noticeable fluctuation in cycle times was observed: it decreased to 21.47 seconds on August 21, dipped further to 20.73 seconds on August 22, and then increased to 24.80 seconds by August 23. The cycle time decreased to 21.74 seconds on August 24, peaked at 25.75 seconds on August 25, and slightly reduced to 25.57 seconds on August 26. This pattern suggests a variability in cycle times that could be attributed to various operational dynamics, such as changes in operator shifts, varying material characteristics at the dig site, or minor variations in equipment performance.

Such data is crucial for identifying potential inefficiencies within the loading and digging processes. By analyzing these time intervals, operational managers can pinpoint areas for improvement, whether in the techniques used, the equipment's maintenance schedule, or the operators' training programs. The aim is to achieve a more consistent and reduced cycle time, which is essential for enhancing the overall productivity of mining operations. This ongoing monitoring and adjustment based on cycle time data represent a critical operational management component in heavy industries.

Table 3. Cycle Time Dump Truck

Cycle Time Dump Truck				
Day	Load Time (min)	Time (transport and return) (minutes)	*Maneuver* (min)	*Cycle time* (minutes)
29.08.2022	2,09	2,12	0,47	4,67
30.08.2022	2,09	2,08	0,37	4,28
31.08.2022	2,09	2,11	0,4	4,61
01.09.2022	1,83	2,11	0,43	4,38
02.09.2022	1,96	2,1	0,42	4,49
03.09.2022	1,95	2,08	0,45	4,49
04.09.2022	2,01	2,1	0,41	4,53

Table 4. Work Efficiency

Information	Excavator	Dum Truck
Available time (minutes/shift/day)	528	528
Obstacles	Minute	Minute
Shift 1 p.m		
Rain & slippery	60	60
Lubricating & refuel	15	15
Malfunction of the appliance	30	35
Total time of constraints	105	110
Standby time (S)	75	75
Repair time (R)	30	35
Adequate working time (minutes)	423	418
Adequate working time (hours) (%)	7,05 = 80%	6,9 = 79%

Cycle Time Dump Truck

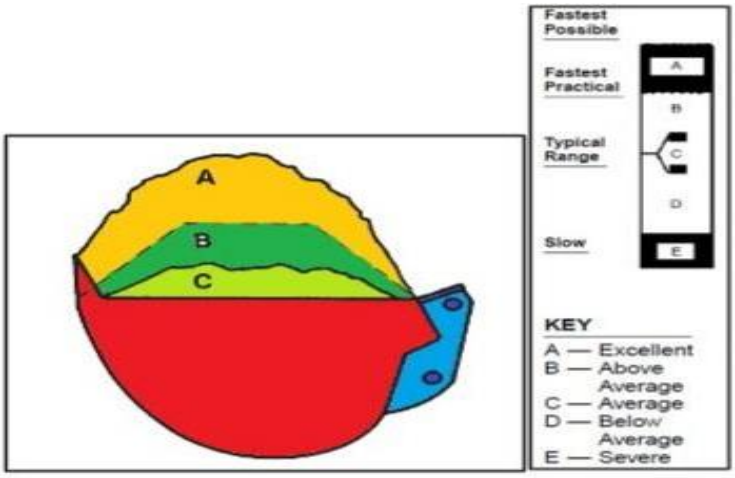
Cycle time for dump trucks, such as the DT Hino 500 monitored in our study, is essential for evaluating the efficiency of transport operations in mining. This metric, detailed in Table 3, reflects the total time required for one complete operational cycle, encompassing loading, transportation, unloading, and return. Over a week from August 29 to September 4, 2022, the cycle times varied: starting at 4.67 minutes on August 29, decreasing to a low of 4.28 minutes the next day, and fluctuating slightly before ending at 4.53 minutes on September 4. These fluctuations may indicate changes in operational efficiency due to factors like haul road conditions, loading efficiency, or maintenance issues. Understanding these cycle time variations is crucial for identifying potential bottlenecks and implementing improvements in transport logistics to enhance overall mining productivity. Each day's data offers insights into the operational dynamics that affect cycle efficiency, guiding targeted interventions to streamline processes.

Work Efficiency

In the study, the work efficiency of the mechanical equipment was analyzed based on a single operational shift. The typical shift duration was 9 hours daily, except on Fridays when the duration was reduced to 8 hours, translating to an average of 62 hours per week, or approximately 8.8 hours per day [12]. Table 4 details the breakdown of how this time was utilized for both the excavator and dump truck. Each machine was scheduled for 528 minutes of availability per shift. However, various obstacles reduced adequate working time. For instance, the excavator and the dump truck encountered 60 minutes of delay due to rain and slippery conditions and spent 15 minutes on lubrication and refueling. Equipment malfunctions further impacted the excavator and dump truck, causing 30 and 35 minutes of downtime. Consequently, the total time lost to constraints was 105 minutes for the excavator and 110 minutes for the dump truck. Additionally, both types of equipment had a standby time of 75 minutes, repair times of 30 minutes for the excavator, and 35 minutes for the dump truck. After accounting for these delays, the adequate working time came to 423 minutes (or 7.05 hours, equating to 80% efficiency) for the excavator and 418 minutes (or 6.9 hours, resulting in 79% efficiency) for the dump truck.

Bucket Fill Factor

In this study, the efficiency of the loading equipment's bucket was quantitatively assessed through the bucket fill factor, which was determined to be 90%. This metric is crucial as it reflects the volumetric efficiency of the excavator's bucket when handling materials. The high % fill factor of 90% indicates that the buckets were filled to 90% of their capacity on average, which is a strong performance indicator, especially considering the material being handled was clay stone—a material known for its varying density and compaction properties [6]. This fill factor is significant as it directly influences the productivity of the loading process; a higher fill factor means fewer trips are needed to move the same amount of material, thereby optimizing the loading phase of operations and enhancing overall efficiency.



Average Bucket Payload =
(Heaped Bucket Capacity) × (Bucket Fill Factor)

Material	Fill Factor Range (Percent of heaped bucket capacity)
Moist Loam or Sandy Clay	A — 100-110%
Sand and Gravel	B — 95-110%
Hard, Tough Clay	C — 80-90%
Rock — Well Blasted	60-75%
Rock — Poorly Blasted	40-50%

Figure 2. Bucket Fill Factor [6]

Sweel Factor

In this study, the swell factor was determined to be 0.74 for clay stone, which was the primary material handled in the field operations [10]. The swell factor is a critical measurement that describes how much material expands when moved from its original position in the ground to a loose, uncompacted state. This expansion impacts the volume calculations essential for determining the efficiency and capacity of hauling operations. As outlined in Table 5, the swell factors for different materials were recorded, ranging from as low as 0.63 for dense materials like 'Batukapur' and 'Rock, blasted and well', to as high as 0.89 for 'Gravel, dry'. Each material type—whether clay, soil, or gravel—shows different swell percentages and corresponding factors, influencing how equipment should be utilized and the expected productivity in various conditions.

Table 5. Swell Factor Material

No	Material Type	Weight, lb per cubic yd		Percent Swell %	Swell Factor
		Block	Loose		
1	Clay, dry	2700	2000	35	0,74
2	Clay, wet	3000	2200	35	0,74
3	Soil, dry	2800	2240	25	0,80
4	Ground, wet	3200	2580	25	0,80
5	Soil and gravel	3200	2600	20	0,83
6	Gravel, dry	2800	2490	12	0,89
7	Pebbles, wet	3400	2980	14	0,88
8	Batukapur	4400	2750	60	0,63
9	Rock, blasted and well	4200	2640	60	0,63
10	Sandy, dry	2600	2260	15	0,87
11	Sandy, wet	2700	2360	15	0,87
12	Shale stone	3500	2480	40	0,71

Table 6. Actual Match Factor

Actual compatibility factor			
Cta	Ctm	MF	means of transport used
268.8	22,45	0,83	2

Calculation of actual match factor

The match factor calculation is crucial for aligning the operational timings between the loading and transport equipment. In this scenario, the loading excavator has a cycle time of 22.45 seconds, while the cycle time for the transport equipment is significantly longer at 268.8 seconds. Given the setup with two units of transport and a total of 5 swings, the match factor was calculated as follows:

$$\text{Match Factor} = \frac{2x5x22,45}{1x268.8}$$
$$= 0.83$$

This value of 0.83 indicates that the loading equipment is underutilized, spending time waiting for the transport equipment to be ready, which suggests an inefficiency in coordinating operational activities. The results are summarized in Table 6, which presents the actual compatibility factors, showing the cyclical and transport times alongside the derived match factor for each unit of transport used.

Enhancing these match factors is critical for reducing downtime and increasing the throughput of mining operations. Adjusting the number of transport units or improving the synchronization of cycles could help achieve a match factor closer to 1, indicating optimal alignment between loading and hauling equipment [6].

Actual Productivity Excavator

The target of Overburden transfer productivity in Pit 1 for *fleet point loading* is 170 Bcm/hour. In contrast, the actual productivity of the loading equipment at the *fleet point loading* can be determined by calculating the capabilities of the loading equipment and transportation equipment based on the supporting data that has been obtained previously. Where CT is Cycle *Time,* BFF is Bucket *Fill Factor*, SF is Swell *Factor,* and E is Efficiency. Actual productivity of the loading excavator at *the Pit* 1 location. For digging tools to load in August 2022. The activity of stripping *overburden* materials using one loading excavator is served by two means of transport.

Where:

P = Loader production capacity (Bcm/hour)
Ctm = Load device circulation time (minutes)
KB = Capacity *Bucket* (m^3)
BFF = *Bucket fill factor* (%)
And = Work efficiency (%)
SF = Swell factor (%)

The total cycle *time of the entire* excavation tool (*cycle time)* of the Sany SY 365 H Excavator in 1 working day is an average of 23 seconds, and the work efficiency of the excavator is 80% (Table 7) The *bucket* capacity needed to meet the unit of the transport equipment is 1.6 m3 with *a bucket fill factor* of 90% and a swell factor of 74%. [4]

Solution for the productivity of digging and loading equipment:

$$P = \frac{3600}{23} x\ 1,6\ x\ 90\%\ x\ 80\%\ x\ 74\%$$
$$= 133,43 \text{ Bcm/Hour}$$

So the average productivity of the loading excavator is 133,43 Bcm/Hour.

Table 7. Actual Productivity Excavator

Actual productivity of digging tools			
Day	productivity Bcm/Hour	Bcm/Hour productivity target	Achievement (%)
20.08.2022	133,43	170	78%
21.08.2022	146,13	170	86%
22.08.2022	153,44	170	90%
23.08.2022	127,87	170	75%
24.08.2022	146,13	170	86%
25.08.2022	122,75	170	72%
26.08.2022	122,75	170	72%
Average	**136,07**		**80%**

Actual Productivity Dump Truck

The productivity target of *overburden transfer* equipment in pit 1 for the fleet point is 85 Bcm/Hour. Meanwhile, the actual productivity of the means of transportation at *the loading point can* be determined by calculating the capabilities of the means of transportation based on the supporting data that has been obtained previously. CT is *Cycle Time*, BFF is *Bucket Fill Factor*, SF is Swell *Factor*, and E is Efficiency [4].

Where:

q1 = Production per cycle (m^3)
Kb = Capacity *bucket* Loading device (m^3)
Bff = *Bucket fill factor* (%)
N = Number of loading excavator passing
Q = Productivity (bcm/hour)
CT = Load tool cycle time (minutes)
SF = *Swell factor* (%)
Ef = Work efficiency (%)

The total cycle *time of* the *HINO* 500 FM 260 JD Dump Truck in 1 working day is 135.52 minutes with an average of 4.67 minutes, the work efficiency of the transport equipment is 79% (Table 8), The *bucket* capacity needed to meet the transport unit is 1.6 m3 with *a bucket fill factor* of 90% with the number of *passing/swing of the* Excavator excavation tool Sany sy 365 H 5 times and swell factor 74%.

Solution for the cycle productivity and transportation productivity:
q1 = KB x BFF x N
q1 = 1,6 x 90% x 5 = 7,2
Q = q1 x 60/CTx EF x SF = 7,2 x 60/4,67 x 79% x 74%
Q = 54,07 Bcm/Hour
So the productivity of the means of transportation is 54.07 Bcm/Hour

4. Discussion

Productivity Inhibitors

Based on direct observations in the field, several problems or inhibiting factors prevent the planned production target from being achieved. The influencing inhibiting factors are the work efficiency of the tool and the cycle time of the tool. The actual equipment efficiency is so bad, and the cycle time is very high compared to the plan because operators, drivers, and mechanics do not work optimally. Where production should be done, but the driver has stopped loading at the disposal, and where should the cycle time, which is not so high, be high because sometimes dump trucks stop by to take drinking water at the hut and stop by the workshop to defecate/urinate which is located in the opposite direction to the disposal. This causes the standby time to be higher than the working time and causes high waiting times during circulation time. Based on various problems or existing inhibiting factors, optimization must be carried out in the tool's cycle time and match factor [13].

Table 8. Actual Productivity Dump Truck

Hino 500 Productivity			
Day	Bcm/Hour Productivity	Bcm/Hour productivity target	Accessibility (%)
29.08.2022	54,07	85	64%
30.08.2022	59	85	69%
31.08.2022	54,78	85	68%
01.09.2022	57,65	85	68%
02.09.2022	56,12	85	66%
03.09.2022	56,12	85	66%
04.09.2022	55,62	85	65%
Average	**56,19**		**67%**

Productivity Optimization

Productivity optimization is essential to achieve the predetermined production target, which is caused by several problems, including the work efficiency of the equipment, the *cycle time* of the means of transportation, and the compatibility factor (*match factor*), so that the optimization of these problems is needed as an effort to achieve the production target [3].

Optimization of Excavator work efficiency

In simple terms, work efficiency can be increased by increasing the duration of effective working hours as much as possible by considering the actual conditions in the field. To increase effective working hours, the duration of each obstacle must be reduced by considering the actual conditions in the field. Is it possible to reduce the duration of the obstacle to be applied. Based on the observation results, the following are the obstacles in the field that make it possible to reduce the duration:

1. Continue excavation and loading after rain when the field conditions are still wet (slippery).
2. Changing the oil change and refueling schedule (lubricating & refueling), usually done during the day, is changed to night.
3. Minimize tool damage during the day by checking and repairing before the digging tool is used.

After reducing the duration of obstacles, the duration of effective working hours for day shifts is obtained:

Effective working (Table 9) hours of day shift = 528 Minutes – 20 minutes = 508 Minutes = 8.4 Hours
The efficiency of the work after the repair is calculated as follows

EK = $\frac{508\ menit}{528\ menit} x\ 100\% = 96\%$

Table 9. Work Efficiency Optimization

Information	Loading Excavator
Available time (minutes/shift/day)	528
Obstacles	Minute
Shift 1 p.m.	
Rain & slippery	20
Lubricating & refuel	-
Malfunction of the appliance	-
Total time of constraints	20
Standby time (S)	20
Repair time (R)	
Adequate working time (minutes)	508
Adequate working time (hours) (%)	8.4 Hours = 96%

Table 10. Productivity Excavator Optimization

Productivity of the digging tool after optimization			
Day	productivity Bcm/Hour	Bcm/Hour productivity target	Achievement (%)
Sany Sy 365 H	160,11	170	94%
Sany Sy 365 H	175,36	170	103%
Sany Sy 365 H	184,13	170	90%
Sany Sy 365 H	153,44	170	90%
Sany Sy 365 H	175,36	170	103%
Sany Sy 365 H	147,30	170	86%
Sany Sy 365 H	147,30	170	86%
Average	**163,28**		**93%**

Calculation of the productivity of the loading excavator after optimization

To optimize the productivity of the Sany SY 365 H excavator, a detailed analysis was conducted using several key performance metrics. The calculation involved the loader's production capacity (P), expressed in cubic meters per hour (Bcm/hour), and factored in the load device circulation time (Ctm), bucket capacity (KB), bucket fill factor (BFF), work efficiency, and swell factor (SF). The cycle time was initially averaged at 23 seconds per cycle, with the work efficiency rated at 80%. The excavator's bucket capacity was set at 1.6 m³, the bucket fill factor at 90%, and the swell factor reflecting the material's expansion post-excavation at 74%.

The productivity (P) of the excavator was then calculated using the formula:

Where:

P = Loader production capacity (Bcm/hour)
Ctm = Load device circulation time (minutes)
KB = Bucket Capacity (m³)
BFF = Bucket fill factor (%)
And = Work efficiency (%)
SF = Swell factor (%)

$$P = \frac{3600}{23} x\ 1{,}6\ x\ 90\%\ x\ 96\%\ x\ 74\%$$

This calculation yielded a productivity rate of 160.11 Bcm/hour on the first day of operation post-optimization. Over subsequent days, productivity varied, reaching as high as 184.13 Bcm/hour and dropping to a low of 147.30 Bcm/hour, reflecting fluctuations in operational conditions and efficiency. As outlined in Table 10, the productivity data shows that the average productivity achieved after optimization was 163.28 Bcm/hour, representing a 93% achievement rate towards the 170 Bcm/hour target (Table 10). These figures underscore the effectiveness of the optimization strategies implemented, which significantly enhanced the excavator's loading capacity and overall operational efficiency.

Table 11. Productivity Cycle Time Dump Truck Optimization

Cycle Time optimization			
Unit/Day	*Cycle time actual*	*Delay time*	*Cycle Time* Optimasi
DT-01	4,67	1,23	3,44
DT-02	4,28	1,28	3
DT-03	4,61	1,23	3,38
DT-04	4,38	1,12	3,26
DT-05	4,49	1,35	3,14
DT-06	4,49	1,96	2,53
DT-07	4,53	1,13	3,4
Average	**4,49**	**1,32**	**3,16**

Table 12. Productivity Dump Truck Optimization

Hino 500 productivity after optimization			
Unit	Bcm/Hour Productivity	Bcm/Hour productivity target	Accessibility (%)
DT-500	73,41	85	86%
DT-500	84,18	85	99%
DT-500	74,93	85	88%
DT-500	77,46	85	91%
DT-500	80,42	85	95%
DT-500	99,82	85	117%
DT-500	74,27	85	87%
Average	**88,29**		**95%**

***Calculation* of Optimized Cycle Time of Transport Equipment**

Table 11 presents the outcomes of optimizing cycle times for the site's seven dump trucks (DT-01 to DT-07). The original average cycle time of 4.49 minutes was reduced to an optimized average of 3.16 minutes, reflecting a significant improvement in transport efficiency. Notable reductions include DT-06, which decreased most from 4.49 minutes to 2.53 minutes. The adjustments made, potentially in routing, loading, and scheduling practices, contributed to these enhancements, underscoring the effectiveness of the optimization strategies in streamlining operations and reducing delays across all units.

Calculation of Transport Equipment Productivity after Optimization

It is known: The total cycle *time of the HINO* 500 FM 260 JD Dump Truck in 1 working day (Table 12) is 135.52 minutes with an average of 3.44 minutes, the work efficiency of the transport equipment is 79%, The *bucket* capacity needed to meet the transport unit is 1.6 m3 with a *bucket fill factor* of 90% with the number of *passing/swing* of the contents of the excavator and loading *equipment Excavator* Sany sy 365 H 5 times and *swell factor* 74%.

Solution for Cycle productivity:
q1 = KB x BFF x N
q1 = 1,6 x 90% x 5
= 7,2
Q = q1 x 60/CTx EF x SF
= 7,2 x 60/3,44 x 79% x 74%
Q = 73,41 Bcm/Hour
So the productivity of the means of transport is 73.41 Bcm/Hour

Match *factor* calculation after optimization

It is known: *The cycle time of* the loading excavation tool is 22.45 seconds, and the cycle time of the transport equipment is 189.6 seconds, with a total of 2 units of transport and five passings.

Solutions for the Match Factor:

$$Match\ Factor \ = \frac{2x5x22{,}45}{1x189{,}6} = 1.18 = 1$$

So it was obtained *that the actual match factor* of 1.18 was close to matching, but the means of transport were still waiting a little (Table 13).

After the optimization calculation, a *match factor* of 1.18 or 1 match was obtained, and the productivity target was achieved with an average achievement percentage of 95%.

Table 13. Match Factor Optimization

Match factor optimization with two units of transport equipment			
Cta	Ctm	MF	Tools Used
189,6	22,45	1,18	3

Table 14. Simulation Match Factor

cta	ctm	MF	Tools Used
269,16	22,45	1	3

Match factor *simulation calculation*
A simulation calculation of the match factor determines the need for transportation equipment to move overburdened *materials.* It is known that the excavation equipment's cycle time is 22.45 seconds, and *the cycle time of* the transportation equipment is 269.16 seconds, with a total of 3 units of transportation and four passings.

$$Match\ Factor\ = \frac{3x4x22{,}45}{1x269{,}16} = 1$$

So after adding one piece of transportation equipment and reducing the number of *passes* to 4 times, a *match factor* of 1 was obtained (Table 14), which was said to be harmonious because both mechanical equipment, namely digging tools, loading and loading, and transportation equipment, were equally busy or no one was waiting.

The productivity analysis at PT. Anugrah Borneo Sinergy highlights significant insights into equipment efficiency and operational optimization by focusing on the digging, loading, and hauling overburden. Informed by the detailed equipment specifications provided by manufacturers such as Komatsu and Caterpillar [1], the study evaluates actual performance against these benchmarks. This analysis resonates with Fanani et al. [2] and Hadi et al. [3], who explored similar productivity challenges in mining operations, emphasizing the importance of aligning equipment capabilities with operational demands.

Further insights from Peurifoy [10] and Indonesian [5], [6] on construction planning and mechanical soil moving underline the critical nature of precise, efficient equipment operation in reducing cycle times and maximizing output. These principles are evident in the optimization strategies employed at PT. Anugrah Borneo Sinergy closely mirrors those outlined by Gusman et al. [15] in their discussion on quality capacity and queuing methods to enhance productivity in mining settings.

Moreover, the broader implications of such productivity enhancements are discussed in the works of Lestari and Farist [17], who analyze the productivity impacts of optimized equipment use in overburden removal. The study at PT. Anugrah Borneo Sinergy aims to implement and refine these strategies, ensuring that each piece of equipment is used to its fullest potential, thereby reducing inefficiencies and increasing overall output. This approach is crucial in a region where mining operations are pivotal to economic stability and growth, as Kurniawan [14] and Isnaeni et al. [19] highlighted in their respective studies on overburden production optimization.

The utilization of advanced analytical techniques to evaluate and enhance equipment productivity supports operational goals and contributes to a body of knowledge that can guide future improvements across the mining industry [16], [18]. The ongoing analysis of cycle times, load capacities, and efficiency metrics provides a clear pathway to achieving and surpassing production targets, setting a standard for future endeavors in similar geological and operational environments.

5. Conclusion
Based on the results of the research on the analysis of the productivity of loading and unloading equipment and transport equipment in the activity of moving overburden materials at PT Anugrah Borneo Sinergy Keramat Mina Village, Simpang Empat District, Banjar Regency, South Kalimantan Province, the conclusion obtained is that the actual productivity obtained from the actual loading and unloading excavation equipment for 7 days while in the field was obtained productivity results of 133.43 Bcm/Hour, 146.13 Bcm/Hour, 153.44 Bcm/Hour, 127.87 Bcm/Hour, 146.13 Bcm/Hour, 122.75 Bcm/Hour, and 122.75 Bcm/Hour, with an average productivity of 136.07 Bcm/Hour, which means that the production target has not been reached, while the actual productivity of transportation equipment for 7 days while in the field has also not reached the production target, the result of transportation equipment

is 54.07 Bcm/Hour, 59 Bcm/Hour, 54.78 Bcm/Hour, 57.65 Bcm/Hour, 56.12 Bcm/Hour, 56.12 Bcm/Hour, and 55.62 Bcm/Hour, with an average productivity result of 56.19 Bcm/Hour.

The compatibility between 1 loading excavation device and two actual transportation tools in the field was obtained with a match factor of 0.83. The compatibility obtained between 1 loading excavator and two means of transport whose cycle time has been optimized was obtained with a match factor of 1.18. The compatibility between 1 loading excavator and three transportation tools was obtained due to the simulation match factor 1.

Factors that hinder the transfer of overburdened materials include waiting time, the length of transportation time and return to the circulation time (cycle time) of the means of transportation, low work efficiency, and the mismatch between the number of loading and excavating equipment and the means of transportation. Where the waiting time, transportation time, and return time (maneuver) affect the amount of circulation time (cycle time) of the means of transportation, the transportation time and return time are caused by human resources factors (operators), while for waiting time is caused by the incompatibility between the loading and excavating equipment and the operating means of transportation.

Productivity recommendations for loading and unloading equipment and transportation equipment. In the productivity of digging and loading equipment, the target has not been reached, while in the productivity of transportation equipment, it has also not reached the target. To optimize the productivity of loading and unloading excavation equipment and transportation equipment, it needs to be considered, namely increasing or increasing the work efficiency of loading and unloading excavation equipment and minimizing the transportation time, return time, and waiting time at the circulation time (cycle time) of the transportation equipment, to obtain the compatibility of the match factor equal to 1. With the productivity results obtained from the optimized digging and loading equipment, an average result of 163.28 Bcm/Hour, and the optimized transportation equipment obtained an average productivity of 88.29 Bcm/hour. So that the production target for loading and transporting excavation equipment is achieved. And with the addition of 1 unit of means of transportation in order to get a match factor equal to 1.

Acknowledgment
We would like to extend our deepest gratitude to PT Anugrah Borneo Sinergy site CV. Banjar Global Mining for providing the necessary resources and support that played a crucial role in the realization of our work.

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